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Intelligent Service Platform of Manufacturing Process and Tool Based on Data Warehouse

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Abstract

Cloud manufacturing takes the advanced information technology as the media to provide life cycle manufacturing resource integration and shares services such as product development and manufacturing. Machine tool as a cloud manufacturing services terminal is an important part of product manufacturing. Machining process and cutting tools as the ways of realizing the manufacturing are indispensable, they are services interface in the cloud manufacturing system. The process data sharing service framework in the cloud manufacturing environment is presented. The basic data of cutting, machining process and tool in data warehouse are the foundation and core of data service in this framework. Data mining technology is taken as data query and processing method. Intelligent matching strategy based on machining feature recognition technique, process parameters and machining tool is established. On the basis of this, the technology of machining equipment inquiry and adaptation method are discussed. Finally, the framework of machining process and tool information service strategy is obtained.

Peer-review under responsibility of the scientific committee of the 5th CIRP Global Web Conference Research and Innovation for Future Production

Keywords: Cloud manufacturing; Intelligent process platform; Data warehouse; Cutting tool selection platform

1. Introduction

Cloud manufacturing is a new model of network manufacturing services with cloud manufacturing service platform and network technology, it is used to manage manufacturing resources and provide services to enterprise users. Cloud computing, high performance computing, networking and networked manufacturing are integrated in cloud manufacturing [1]. The various types of manufacturing resources and capabilities are integrated in cloud services, which manage cloud services intelligently, provide safe, high quality and cheap cloud service to enterprise users. The concept of cloud manufacturing is manufacturing as a service, and based upon this all kinds of manufacturing resources and manufacturing capacity are virtualized as a service, forming a sharing service platform of manufacturing resources and manufacturing capacity to achieve a safe, reliable, high-quality and cheap manufacturing life cycle service.

Bohu Li, et al. [1] first proposed the concept of cloud manufacturing and the operation mode, and proposed the five layer system structure of cloud manufacturing (including the application layer, application interface layer, core resource layer, virtual resource layer, physical resources layer). Xu [2] proposed a 4-layer cloud manufacturing system structure that is the application layer, global service layer, the virtual service layer and manufacturing resources layer. Besides, many scholars have proposed other cloud manufacturing systems [3-6]. However, no matter in which system NC machine tool is in the manufacturing cloud physical resources layer. Machine tool is an effective way to achieve high efficiency, automation and flexible manufacturing which plays an irreplaceable role especially in small batch, complex shape, and high precision parts manufacturing. Machining process is the most important resources of machining and the powerful guarantee to promote the quality of the products, improve production efficiency and reduce the manufacturing cost.

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The combination of computer technology, process optimization and cutting techniques is achieved firstly through the cutting database. In 1964, the database technology was introduced to the field of metal cutting by United States. The database was researched and developed by AFMDC, which contains more than 3750 workpiece material, 22 types of cutting parameters of processing methods. In 1971, Germany also established a cutting data Intelligence Center (INFOS), it became one of the world's largest cutting databases. After 40 years' development and improvement, more than 30 metal cutting databases are applied to the practical production[7, 8]. Metal cutting database has brought considerable economic outlook for the mechanical processing industry, the International Institute for Production Engineering Research (CIRP) proves the cutting database can make the processing cost of the enterprise to improve reduced by 10% or more through investigation, the research will effectively improve cutting production efficiency [9, 10]. Beijing Institute of Technology has built difficult to machining materials cutting database, coating hard alloy cutting database and coated cemented carbide tool expert system of cutting database since 1986. Shandong University studied the cutting database since 2001, developed some cutting databases aiming at high-speed cutting and difficult-to-machine materials [11].

The optimization algorithm and artificial intelligence can be introduced into the original database system, which becomes main direction of scholars' research. For instance, P.G.Mcropoulos et al. developed an intelligent tool selection system according to the basic principle of metal cutting which could predict new processing conditions based on the existed cutting data. Optimization methods such as the neural network algorithm, particle swarm optimization algorithm, and genetic algorithm are applied to cutting data, obtaining functions of tool wear prediction and cutting parameters optimization. At present, the most mature tool cutting database is manufacturer's tool selection for users. Sandvik Coromant developed a tool management software which can automatically choose the tools from the company's electronic samples and provide information of cutting parameters and tool life.

CAPP has the advantages of improving the efficiency of process design, reducing the cost of process design and shortening the production cycle. Process method and tool performance changed constantly with the development of cutting and tool technology, and the service process won't be able to provide better service unless be timely updated. Therefore, the sharing of processing technology is effective in order to make cutting tools, machining centers and other manufacturing terminals better served for customer. Workpiece materials, machine tools and cutting tools related to processing technology will affect the development of processing technology. Among them, cutting tools have the higher degree of standardization and stronger versatility, thus, this article explores the methods of sharing and service of the processing based on the cutting tools.

2. Basic Framework for Process Cloud Services

NC machine tool as one of the cloud manufacturing terminals is an important part of the product manufacturing, machining process and cutting tools are essential part for CNC machine tool working. Therefore, machining process and tool service are essential link in cloud manufacturing. The size of the processed workpiece and the accuracy of the information are released to the process server through the cloud, process server decomposes the processing characteristics of the parts. The part materials, processing characteristics and requirements of machining are matcher in the server, and the right machine information will be transferred to the process server, combined with the cutting tools matching the processing. Eventually, the information of cutting tools is transmitted to the user or manufacturer, providing solutions, arrangement in the process and choice of cutting tool, as shown in the Fig. 1.

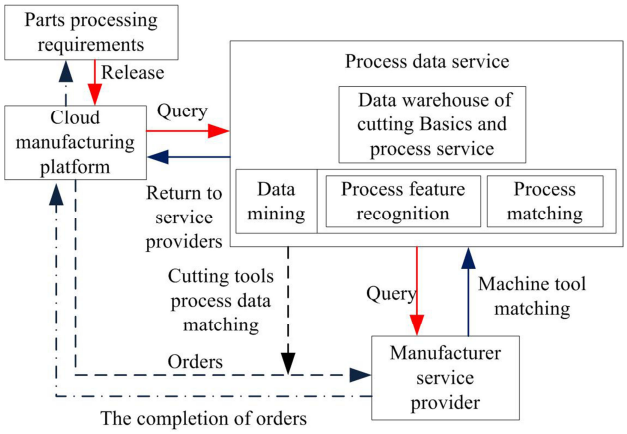

Fig. 1. Process of intelligent cutting tools and process service platform.

3. Technical Service Framework

3.1. Establishment of Basic Database Based on Data Warehouse

The core part of service platform is the process database, however, the problems of existing system database are the complex data stored in the data system. Large amount of information, strong service ability, long construction period, resulting in the database data lags far behind the level of manufacturing technology. Data warehouse is a subject-oriented, integrated, non-volatile, time-varying data set, it is used to support management decision-making. It is a key technology for OLAP analysis, data mining, data storage, data organization and data integration. The operation data can be effectively integrated into a unified environment to provide decision-making data access, so that users can easily and quickly check the needed information and decision support. Data warehouse technology has been applied in a number of enterprises and business services with good prospect. There is less data warehouse application research in cutting database, Xinling Zhang introduced data warehouse technology to grinding data sharing platform, constructed data warehouse according to the characteristics of grinding process data, and analyzed the multidimensional data set in the warehouse[12].

Processing technology is decided by the workpiece materials, characteristics of workpiece, machining methods, cutting tools and machining quality requirements jointly, therefore, the above information is needed to be collected, managed and stored into the data warehouse in unified format :

1) Material and cutting knowledge base

Material and cutting knowledge base includes basic information of materials, cutting mechanism, cutting tool geometry, material information, basic characteristics of machine tool, and so on.

2) Process classification of machining features

The cutting tools are various in different process, machining parts and processing position. It is need to decompose parts to basic characteristics elements based on machining features. Generally, typical parts consist of plane, groove, surface, shoulder, hole and so on, and can be refined according to different processing position and rough machining\semi finish machining\finishing processing characteristics.

3) Identification and Evaluation of Cutting Tool and Machine Tool Dynamics

The change of cutting layer dynamic has great influence on cutting process dynamics performance. Identification and evaluation of cutting tools and dynamic performance of machine tool can evaluate milling stability more accurately, meet the machining requirements and match the corresponding machine tool.

4) Matching Rules between Workpiece Materials, Cutting Tools, Process Parameters and Machining Path

Factors such as machining process, workpiece material, cutting tool, process parameters, processing path will affect the processing results. Besides, hardness mutation, shaped corner surface and curvature mutation have great influence on planning of cutting parameters and machining path. The basic matching rules of various factors are added in the database, so that the process data will be more accurate. The process of cutting contains lots of information, so single processing information should include information of material, cutting tool, machine tool, workpiece characteristics, and process parameters, and so on, which brings complexity to the subsequent classification and data processing. Standard process information database is established according to the material processing and processing characteristics. The added data based on rule-based reasoning and case-based reasoning hybrid forward reasoning method to classify the process information, so the new data can inherit some of the characteristics of the basic data with the convenience of subsequent data mining analysis. The process of information processing is shown in Fig. 2.

The data warehouse technology is used to build the basic database based on the classification of the processing feature and cutting knowledge base. Cutting basic physical data warehouse consists of workpiece information repository, tool information database, information library of cutting tool, tool path information database, processing characteristic database and basic cutting data. The process rule as the knowledge base and constraint conditions is used in optimization and data mining. The basic data consists of experimental data, the simulation data, the knowledge, literature data and field data processing. These data are loaded into data warehouse through data entry with the ETL tool extracting, cleaning and transforming the data before inputting it to provide convenience to the data warehouse storage and query. Customer can extract from the data warehouse to get a certain subset according to their needs, to meet customer requirements on application analysis and reporting. Data cube can be established by data mart, such as three-dimensional data cube composed of machining feature, cutting tools and cutting parameters. Do on-line analysis processing (OLAP) operation to the data cube by drilling down, rolling up, slicing and dicing. In addition, the data in the data warehouse can be used in data mining, statistical analysis and data optimization. Finally, display and present the results through the query, analysis and reporting tools. Data warehouse establishment framework is shown in Fig. 3.

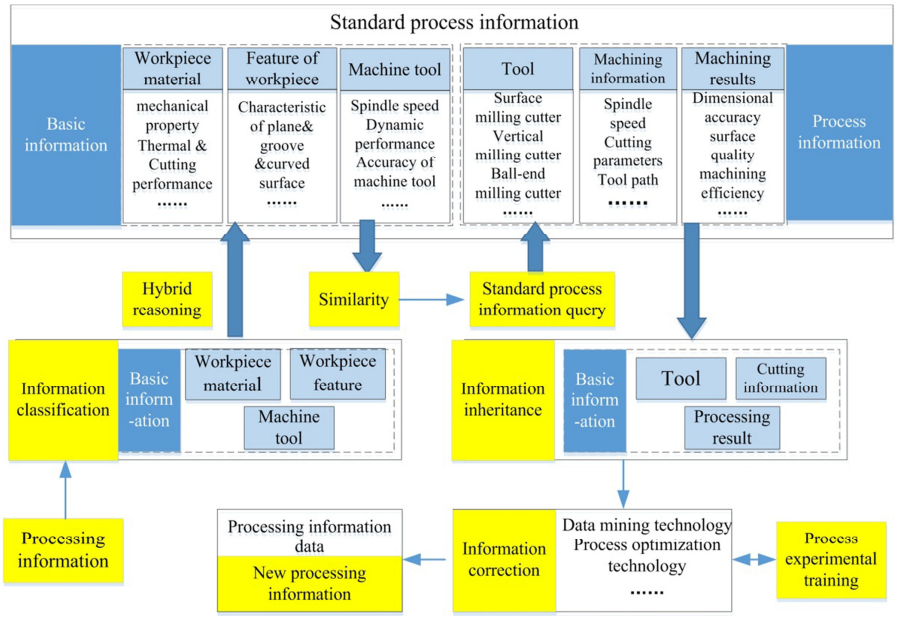

Fig. 2. The process of information processing.

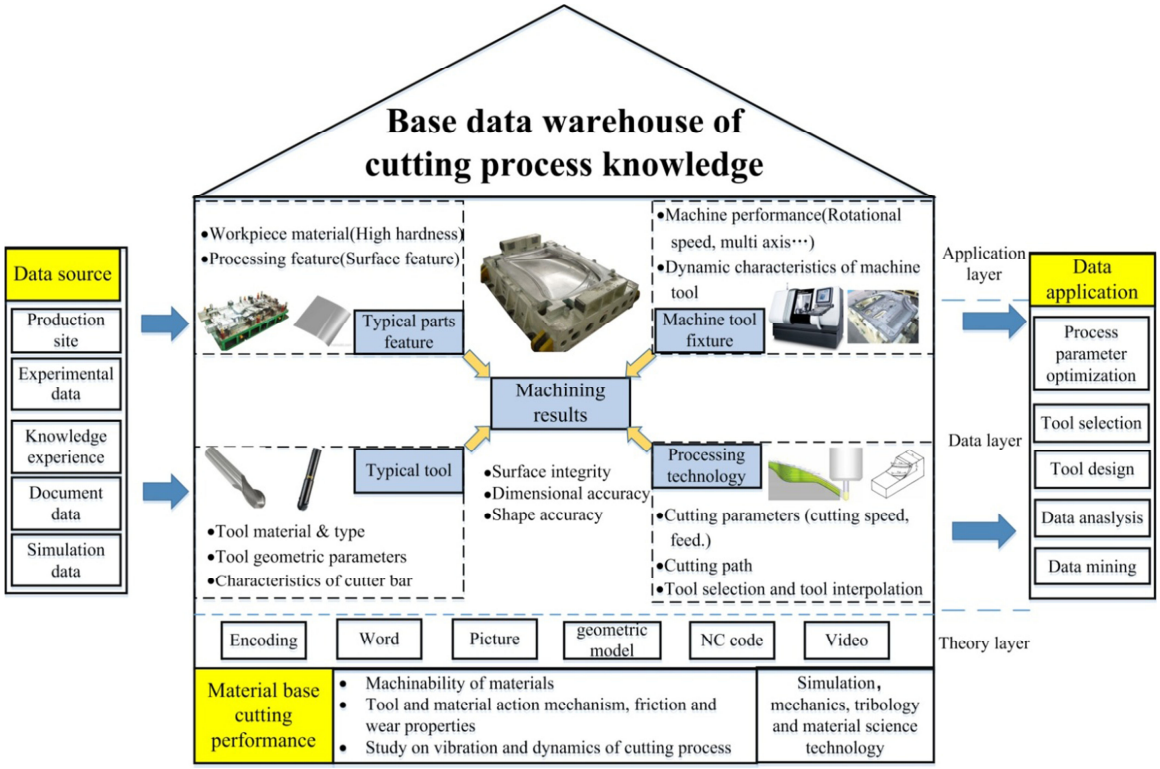

Fig. 3. Base data warehouse of cutting process knowledge.

3.2. Information Query Based on Data Mining

The application of data warehouse can service for customer after establishing the data warehouse. Data mining technology can be applied to analyze the data to find the information that users are concerned about. Data mining has analytical methods such as the correlation, classification, prediction, which can be used to analyze the data in the data warehouse. The information of the workpiece, machining features, machining tools, cutting tools, cutting parameters and machining path can be obtained through association rule mining, which can provide data support to the optimization of process parameters. The classifying and predicting method are taken to classify the same processing characteristics of process parameters according to the process and results of the processing. The parameters can be categorized to find relevant data quickly when selecting, improving the speed of process optimization. Cluster analysis method can be used in the process of finding similar information in warehouse and clustering the information, a cluster of data can be seen as a whole to reduce the amount of data optimization. The regression forecasting method is used to predict the processing results of a part by using the method of data mining. The above method are used in the platform for process optimization, tool selection and process optimization. Genetic algorithm, neural network, particle swarm optimization algorithm are integrated to data analysis for different optimization objectives.

In the machining, different cutting tools can be used to achieve the same feature, so one of the important keys for machining is choosing the right tool. The characteristics of cutting tool in different processing are defined as the basic principle inputting into data warehouse. The available tools are sorted as their applicability according to the evaluation criteria and set the optimization goal to get suitable tool and process parameters. The process is shown in Fig. 4.

Processing equipments in different processing service enterprise are not same, and neither does the processing of one product with different machine tools. Therefore, it is necessary to consider the difference of machine tools in the process of establishing the processing service. Collect each machine's basic information at the data cloud or the enterprise data terminal according to the equipment performance and the machining characteristics.

Train data are collected through intelligent machine or networking constantly. The data are tracked and calibrated by standard laboratory or processing data. The impact factor of machine can be obtained by comparing with benchmark data. The process parameters can be optimized on the cloud platform and most suitable process parameters for this device can be obtained.

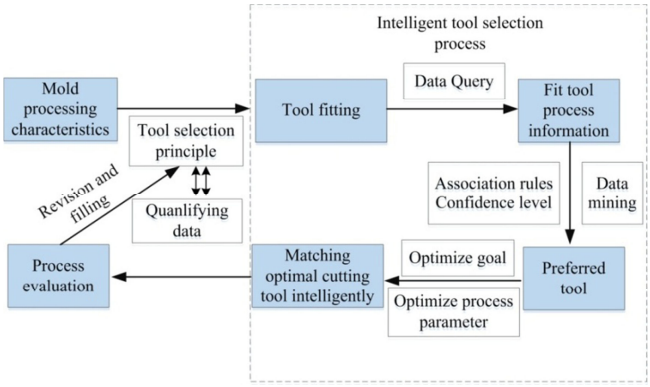

Fig. 4. Intelligent selection process of tools.

4. Research on the Application Technology of the Basic Database

The final purpose of using data mining technology to optimize the parameters based on the data warehouse is application and the service strategy of the application is shown in Fig. 5. Firstly, process data are obtained through the collection and monitoring client and are cleaned up and transformed to standard data. These data are processed by the enterprise server and then loaded to the cloud, stored in data warehouse through ETL tools from cloud processor. Enterprise engineer or remote engineers submit their requested service through the cloud server. The cloud server will sent back the require data to the client from data warehouse after being queried, extracted and processed by the mining reasoning machine. The optimization strategies are transferred through the client APP or reporting tools, and whether the strategies are adopted it or not finally decided by the engineer. At last, decision rules and process data are stored in the server, which provides service interface to cloud based and intelligent manufacturing.

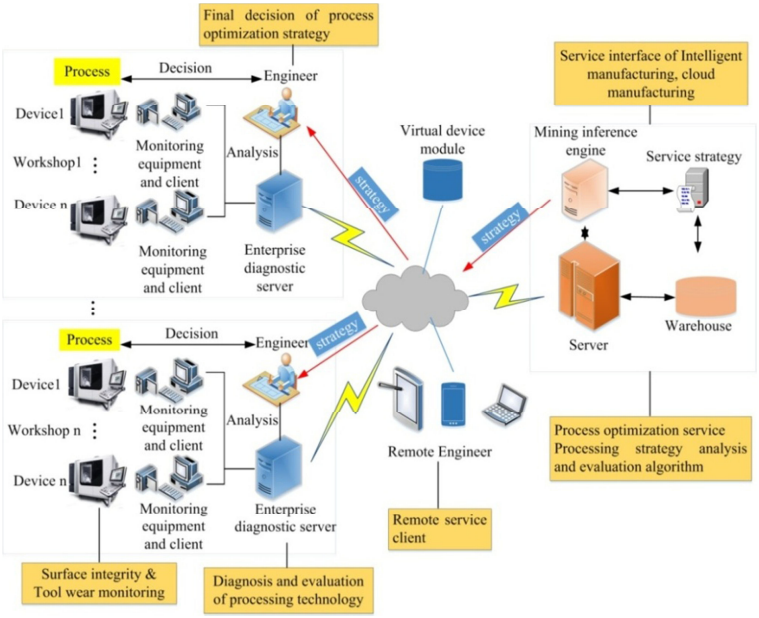

Fig. 5. Applications service strategy of database.

4. Conclusion

Cloud manufacturing as a new mode of service for network manufacturing provides a new solution for the realization of the transformation from production-oriented enterprises to service-oriented enterprises and the optimal allocation of manufacturing resources. An intelligent service platform of manufacturing process and tool is a partial part of the process service was analyzed, and the process services strategy framework was planned. The data warehouse method was proposed in consideration of the large amount of basic processing information data. Basic information of cutting processing, feature machining process information, workpiece material, tool and process parameters were collected to establish data warehouse technology. Based on the data warehouse, the data mining method was used to query processing information, match processing according to hardware such as machine tools and cutting tools provided by manufacturer and adapt basic process information to the equipments. This paper presents the application strategy framework of process service on the basis of the above research. The classification method to verify the collected information will be discussed in future research.

Acknowledgements

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